BUILD A STEP ATTENUATOR

Increase the accuracy of RF measurements with this useful workbench accessory.

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As any radio engineer, technician, or hobbyist will tell you, the heart of any radio-frequency (RF) circuit is some form of tuned circuit. Examples of that include antennas and filters. Unless those tuned circuits are adjusted correctly, any radio or RF device becomes about as useful as a winter coat on a warm summer day.

You might have just built an RF circuit, repaired a radio, or maybe you've tried to troubleshoot a nonworking receiver. Are those IF (intermediate-frequency) transformers set properly to give the right bandpass? Will that filter provide enough rejection to eliminate unwanted signals?

If you need to be able to take readings of tuned circuits, filters, antennas, and other radio-frequency equipment, then the step attenuator presented here is the perfect addition for your workbench. With the ability to set precise 1-dB steps of attenuation, the unit is an easy way to answer all of your questions.

Step Attenuators in Use. Let's take a look at a bandpass filter that might be used in a shortwave radio. A typical circuit might be designed like the schematic diagram shown in Fig. 1. With the values shown, that circuit should be able to pass any signal between 5.95 MHz and 6.6 MHz in the 49-meter band; any signals outside those limits should be rejected and not pass through. If everything is aligned properly, the response of the circuit should be similar to the graph shown in Fig. 2. Notice that the filter has two end sections that are tuned to the center of the passband and two rejection circuits in the center. Rejection circuit L1/C2 is tuned below the passband while L2/C3 is tuned above. Those rejection circuits produce the deep notches in the passband.

If you are building or aligning that circuit, one approach would be to first isolate the end sections by disconnecting L1/C2 and L2/C3. Each end section would then be tuned to the center frequency of 6.267 MHz; a dip meter could be used for that task. The rejection circuits would also be set to their frequencies above and below the passband at 7.456 MHz and 5.267 MHz respectively.

Connect it back together and what do you have? Theoretically, you should have an aligned and properly working bandpass filter. However, if anything was disturbed or reconnected incorrectly, all of your work was for nothing. To be sure, let's check it and find out.

You will need an RF-signal generator with a 50-ohm output that covers the frequency range of the filter (at least 6.6 MHz in this case), a step attenuator, and an RF meter with a 50-ohm input. The RF meter does not have to be calibrated; it will be used to compare the level of two signals. Various commercial RF meters are available, but they tend to be too expensive for the home workshop. Alternatives are to borrow one, purchase a used unit, or build one yourself. In the event that you want to try building your own, plans have been published in various magazines over the years; a suitable unit is the author's "dBm Meter" that was published in the November, 1995 issue of **Electronics Now**.

The equipment is set up as shown in Fig. 3. Set the signal generator for a continuous signal with no modulation to the center of the passband. Set the step attenuator for 0 dB and note the reading on the RF meter. Now switch in 3 dB of attenuation on the step attenuator and note the reading on the RF meter. Switch out the 3-dB attenuation and then tune the signal generator lower in frequency until the RF meter has the same reading as it did when 3 dB of attenuation was

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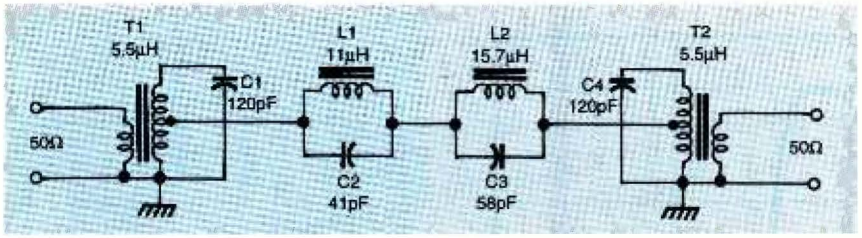

Fig. 1. This schematic diagram is a typical bandpass filter for a receiver in the 49-meter band. If you'd like to build this circuit, wind all of the inductors on T50-6 toroidal cores. Transformers T1 and T2 have a six-turn winding and a 36-turn winding with a center tap; L1 has 52 turns and L2 has 62 turns.

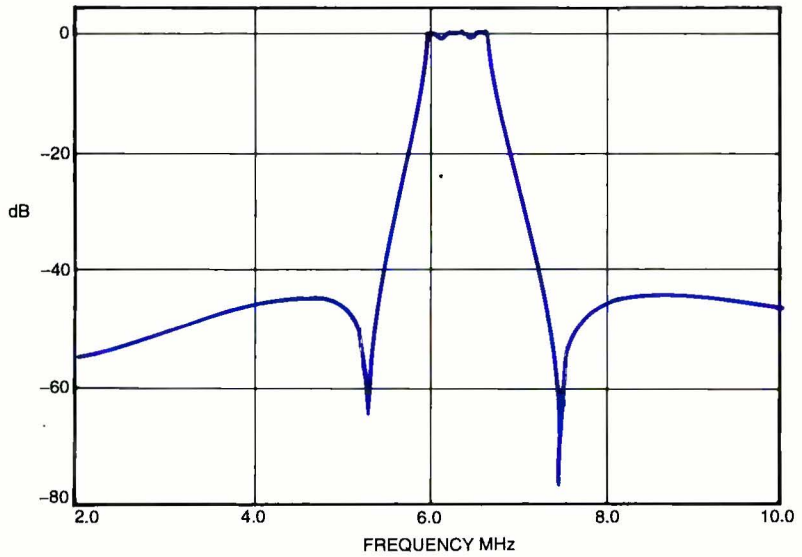

Fig. 2. The frequency response of the filter circuit in Fig. 1 has a passband between 5.95 MHz and 6.6 MHz.

switched in. That frequency will be the 3-dB down point on the lower edge of the passband. Read the frequency. A frequency counter may be helpful here, but it is not absolutely necessary if the signal generator is reasonably accurate.

Tune the signal generator up above the center frequency until the RF meter again registers the same attenuation level to get the 3-dB down point for the upper edge of the passband. Then record the frequency.

Repeat the entire procedure with 6 dB of attenuation switched in. Record the upper and lower frequencies at 6 dB down. Continue to do that with increasing steps of attenuation, such as 10 dB, 15 dB, 20 dB, 25 dB, and so on down to around 40 dB or so. From the recorded frequencies, you should be able to mark measured points on a graph similar to Fig. 2. Note that once you get past around 45 dB down on the example filter of Fig. 1, you can get both sides of the rejection notches.

The results of the author's test on the filter circuit in Fig. 1 is shown in Fig. 4. Each dot represents one measured point. Comparing the plots in Figs. 2 and 4 show some differences. The differences between theory and reality is due to how accurately the inductances of the coils are set by squeezing or spreading the turns on the coils and due to stray coupling between the filter elements. Thanks to the step attenuator, those differences are not due to the measuring instruments.

With that example, you can see that the step attenuator is very useful for finding accurate relative-dB levels. Of course, that is only one example of the use of a step attenuator. Since step attenuators can be expensive to purchase, it is worth the effort for the home experimenter to build one. Let's take a look at how step attenuators are designed.

A Step Attenuator Circuit. The circuit for the step attenuator is shown in Fig. 5. A series of double-pole, double-throw switches, S1–S8, are wired to pass a signal directly through from J1 to J2 when they are switched in one position. In the other position, three resistors dissipate or attenuate some of the signal. The resistor values in ohms are selected to provide a specified amount of attenuation and also provide a 50-ohm match to both the input and output terminals.

Because the attenuator circuit maintains a 50-ohm match in either switch position, the circuit is designed to let several circuits with different attenuation be connected together in series. The various combinations of circuits set a particular value of attenuation. For example, attenuations of 1, 2, 3, 5, 10, and 20 dB can be combined for any value from 0 to 41 dB. Although six attenuators with the binary values of 1, 2, 4, 8, 16, and 32 dB could be used to set any value from 0 to 63 dB, it is easier to use the decimal values and just add two additional 20-dB circuits. Besides being easier to add the individual values together in one's head, all values from 0 to 81 dB in 1 dB steps can be

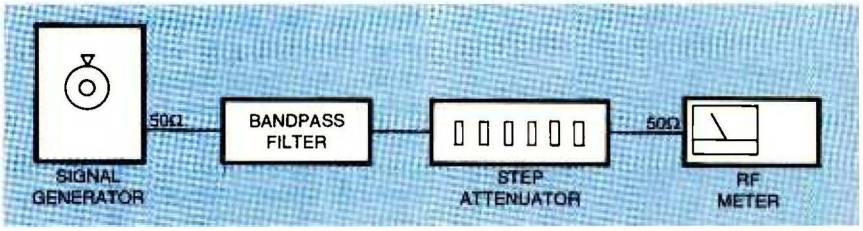

Fig. 3. To use a step attenuator to test a bandpass filter, a signal generator is connected to the circuit under test. An RF meter is connected through the step attenuator to the output of the circuit. Noting the drop in the RF meter with the step attenuator switched in gives you a power level to find the frequency that will attenuate the signal with the attenuator switched out.

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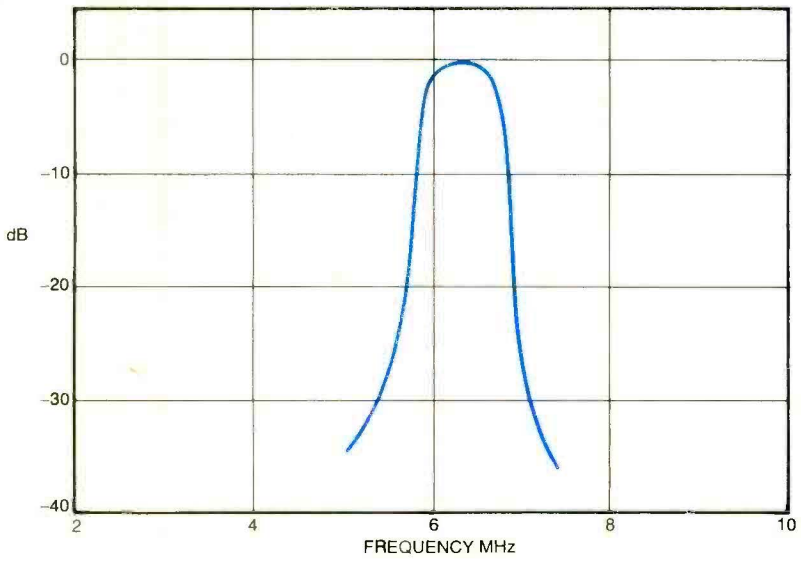

Fig. 4. Here is the plot of the circuit in Fig. 1 as built by the author. Variations between this plot and the one shown in Fig. 2 reflect variations in the circuit and what it is theoretically capable of.

set—a very useful range.

You might be wondering why we're using multiple 20-dB circuits instead of a single 40-dB circuit. If you try to attenuate too much in one circuit, you will soon find out that at radio frequencies, the switch itself will provide some coupling from input to output, even with no resistors connected. That coupling is due to stray capacitances and inductances within the switch. The switches used in the author's prototype measured a 35-40-dB attenuation at 20 MHz before any resistors were added. Because of that limitation, 20 dB is about the largest attenuation value that should be used on any one circuit. Note that commercial step attenuators costing hundreds of dollars also have 20 dB as their largest single step.

Note that the resistor values used in the step attenuator are not the usual 5% values. Although selecting the nearest 5% value will give acceptable results, better accuracy is achieved with the 1% values shown. If you're going to make the effort of building your own unit, it makes sense to build the best instrument that you can.

Building the Step Attenuator. The step attenuator is very simple to build. The photograph in Fig. 6 shows how the layout of the components follows the schematic diagram. In general, slide switches will provide better isolation than toggle switches for the higher dB stages; slide switches are good choices if you cannot measure the isolation of any other type of switch first. A small metal box should be used to

PARTS LIST FOR THE STEP ATTENUATOR

RESISTORS

(All resistors are ¼-watt, 1% units.)
R1, R3—866-ohm
R2—5.75-ohm (see text)
R4, R6—432-ohm
R5—11.5-ohm
R7, R9—294-ohm
R8—17.4-ohm
R10, R12—178-ohm
R11—30.1-ohm
R13, R15—95.3-ohm
R14—71.5-ohm
R16, R18, R19, R21, R22, R24—61.9-ohm
R17, R20, R23—249-ohm

ADDITIONAL PARTS AND MATERIALS

J1, J2— BNC chassis-mount connectors
S1–S8—Double-pole, double-throw slide switches
Case, wire, ground lugs, hardware, etc.
Note: The following item is available from: Unicorn Electronics, Valley Plaza Drive, Johnson City NY 13790; Tel: 607-798-0260; Web: www.unicornelex.com: A complete kit of all parts including a drilled box, $23.95 plus $3.50 for shipping and handling. NY residents must add appropriate sales tax.

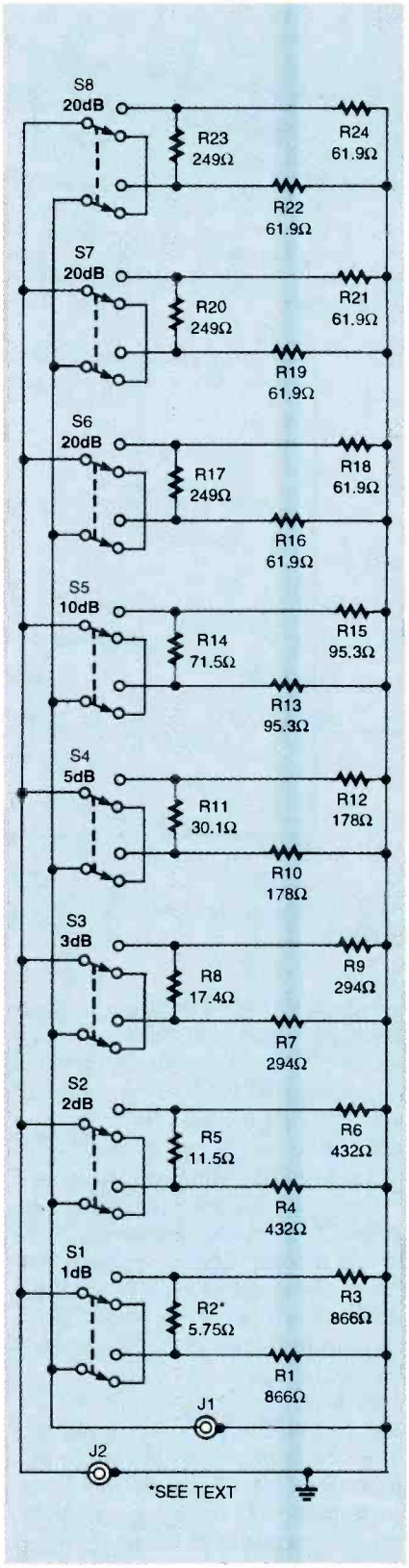

Fig. 5. The step attenuator is simply a series of resistors that are designed to add a certain amount of attenuation between J1 and J2. The resistors can be switched in and out at will to add different amounts of attenuation in 1-dB increments. Since the value of R2 is not commercially available, use two 11.5-ohm units in parallel.

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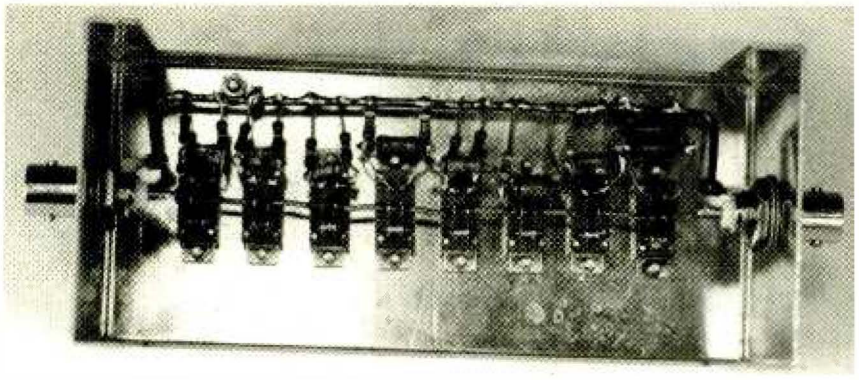

Fig. 6. The step attenuator is a simple layout that is very similar to its schematic diagram. Since good grounding is very important to the circuit, a heavy bus bar is used for connecting together the grounded resistors.

provide an electrically shielded container; any signals will be kept from radiating outside the box. The author's prototype measures about 2 inches by 2 inches by 4½ inches.

Rectangular openings for the slide switches are cut by first drilling two 3/16-inch diameter holes; file out the remainder of the opening with a tiny square file. A drilled and filed box is available as part of a complete kit from the source given in the Parts List. Two BNC connectors for J1 and J2 should be mounted in the ends of the case.

One set of contacts on each switch needs to be connected together with a short length of bus wire. An additional pair of bus wires is used to connect J1 to one common terminal on the switches; the other common terminals are connected to J2.

A good grounding bus will be needed to connect all of the parallel resistors together. A 14-gauge or larger bare copper wire is connected between the ground lugs of J1 and J2. Add at least two more ground lugs equally spaced along the length of the wire, and fasten them down with small screws directly to the front of the box.

Connect the resistors directly to the switch terminals and the ground bus using the shortest lead lengths possible. The path from the end of a resistor to the bus wire should not be more than ¾-inch. If necessary, add another ground lug to shorten the distance. Once the grounded resistors are installed, add the final resistors between the switch terminals, keeping the leads as short as possible.

A final note on the subject of resistors is the value of R2. Since that value is not a standard value, two 11.5-ohm resistors are wired in parallel; as you know, the resulting resistance of two resistors in parallel with the same value is half of the value of one of the resistors.

Once dry-transfer labels are applied to the front panel and the case is closed up, you have an accurate step attenuator. Not only can a step attenuator be used for checking the passband of IF transformers and crystal filters, it can be teamed up with a sensitive RF voltmeter to measure and compare signal levels passing through any receiver circuit including amplifiers, mixers, and tuned circuits. In short, if you work with RF, you're sure to find that a step attenuator is a useful addition to your workshop. Ω

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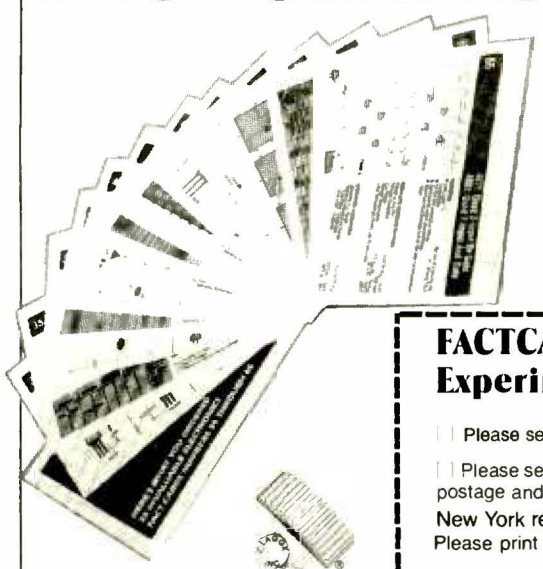

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